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VIBRATION ANALYSIS: AN INTEGRAL METHOD FOR TESTING OF CERAMIC COMPONENTS

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Motivation

The increased application of high-performance ceramics, functional ceramics, and ceramics in composite materials imposes high demands on material properties and the absence of defects. Even the smallest of flaws – especially cracks – can lead to total component failure. Very often one is faced with the task of testing large numbers of components with only moderate efforts and costs.

Vibration analysis is a nondestructive method that can be used to identify a multitude of nonconformities. Any features that influence the vibration properties can be sensed. These especially include inner and surface connected flaws in parts otherwise considered to be defect-free. If applicable, the vibration analysis yields the information needed rapidly and therefore cost-efficiently. At Fraunhofer IKTS, a wealth of experience in the vibration analysis of (sintered) metal parts and tissue products is currently being applied towards quality assurance of ceramic components.

Challenges and features

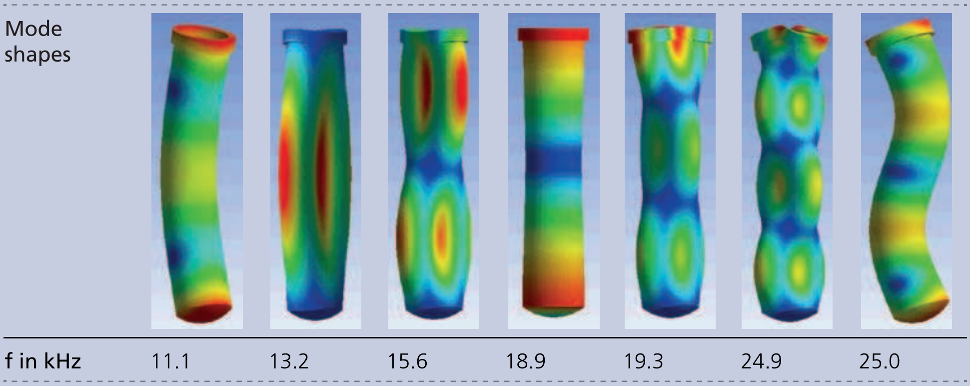
A part is usually excited by impact and vibrates freely. The support should not significantly influence the vibration. However, even if it does, some influences can be tolerated, as long as they involve vibrational modes that are not necessary for the assessment of the part quality. This requires optimization of the positions and the nature of the support. For the same reason, detection has to be nearly free from feedback.

Characteristics

As an integral testing method, vibration analysis yields a number of global parameters such as resonant frequencies and damping constants for various vibrational modes. These quantities are influenced by both intolerable changes in geometry, micro-, and macrostructure (= defects) and "normal" variations in geometry and mass. Therefore, reliable defect detection requires the selection and combination of appropriate features.

Application example 1: Ceramic electrolyte tubes

Na-ß-aluminate electrolyte tubes (Figure 1) show relevant resonance at frequencies above 10 kHz (Figure 3), which can be sensed by high-quality microphones. The tubes are excited by an automated clapper. For the present investigations, five tubes were used: three good parts, one with an increased leak rate, and one with a crack. It was first verified that tube detection was possible (detection rate: 99 %), irrespective of the striking position. After that a good/bad decision was made for unknown cups using a statistical model based on two good tubes as references. The remaining tubes ("Good3", "Leak", and "Crack") were compared to this model using two striking positions (P1 and P2). The following table shows the detection rates, which, with the exception of striking position P1 with a crack, were higher than 90 %. From this result, it was concluded that differentiation between good and bad parts was possible. Furthermore, the need for several striking positions for cups with cracks was recognized.



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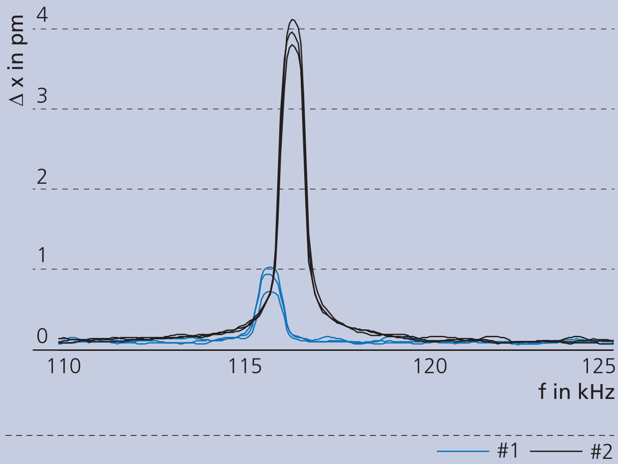
Detection rate for good/bad sorting of tubes "Good3", "Leak", and "Crack" and striking positions P1 and P2

Name	Position	Detection rate
Good3	P1	96 %
	P2	98 %
Leak	P1	98 %
	P2	100 %
Crack	P1	16 %
	P2	92 %

Selected eigen frequency of a cylindrical ceramic hollow part



Application example 2: Cylindrical ceramic hollow part

As expected, the FEM simulation of the part with a length of only a few millimeters (Figure 2) only revealed significant resonance at relatively high frequencies of more than 100 kHz. Hence, the usual method of mechanical excitation along with vibration detection by microphones could not be used, and wide-band excitation by a laser pulse and detection by a laser vibrometer were employed instead. After the excitation and detection positions were optimized, significant eigenmodes could be identified and evaluated. For the sake of clarity, a single peak in the full vibration spectrum was selected. The complete measurement cycle – including positioning of the part in the measurement setup – was repeated three times. The resonant frequency was completely stable for each part, but the good/bad sorting results differed significantly. Further investigations will show how flaws can be distinguished from other (tolerable) variations in the parts.

Summary

Vibration analysis must be adapted specifically to each part and to each defect type for a given part. This adaptation includes selection of an appropriate means of signal excitation and signal detection, signal preprocessing, and compensation of tolerable property changes (e.g., mass and geometry variations) as well as automated evaluation of signals and sorting into "good" and "bad" parts.

Services offered

The applicability of vibration analysis for customers' parts can be examined. If the analysis yields a positive result, the customer can order the on-site design, setup, and leveling of a testing device. This includes installation of automated data evaluation systems and appropriate training.

1 *Ceramic cup with automated mechanical excitation and microphone.*

2 *Cylindrical part with excitation laser (green) and detection laser (red).*

3 *FEM simulation of the mode shapes and their eigen frequencies in kHz.*

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